The Florida Phosphorus Index: A Phosphorus Risk Assessment Tool

Phosphorus Concerns in the Environment

Eutrophication is caused by nutrient enrichment of a water body. Nutrient movement in runoff and erosion from agricultural nonpoint sources is therefore a resource management concern. The movement of phosphorus in runoff from agricultural land to surface water can accelerate eutrophication. Undesirable aquatic plant growth may result from additions of phosphorus to the water. The net result of the eutrophic condition and excess plant growth in water is the depletion of oxygen in the water due to the heavy oxygen demand by microorganisms as they decompose the organic material. Little attention has been given to management strategies to minimize the nonpoint movement of P in the landscape, because of the easier identification and control of point source inputs of P to surface waters and a lack of direct human health risks associated with eutrophication. Phosphorus is generally the limiting nutrient in fresh water systems and any increase in P usually results in more aquatic vegetation. Society is concerned about maintaining clean drinking water. This concern includes a cost for removing the color, taste, and odor associated with high eutrophic condition in surface water due to excess nutrients.

Introduction

The Phosphorus Index (P Index) is a site-specific, qualitative vulnerability assessment tool. This tool allows a conservation planner to determine sites that are potentially most vulnerable to off-site movement of phosphorus. The P Index is used to determine where the application of manure/organic by-products should be based on either a nitrogen-based nutrient budget or a phosphorus-based nutrient budget. The P Index is NOT to be used in any area designated as phosphorus limited by legislation (e.g. Apopka Basin, Everglades, Green Swamp, and Okeechobee Basin) to determine if a nitrogen-based nutrient budget can be used. These areas are to have phosphorus-based nutrient budgets regardless of the nutrient source or soil type. The P Index should, however, be used in these areas to implement conservation practices to reduce phosphorus movement.

The P Index is a science-based, decision-making tool that will support conservation planning and component planning of nutrient management. The purpose of the P Index is to aid planners and others in the decision-making process involved in designing conservation plans related to land application of animal wastes. Concerns regarding P management of manure/organic by-product recycling can be effectively communicated to landowners if the P Index is consistently applied.

Scientific Support

The following individuals are members of the Florida Phosphorus Work Group and are instrumental in the development and maintenance of the P Index:
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Florida Department of Agriculture and Consumer Service (FDACS): J.C. Love and D. Smith.

The P Index assesses two major categories of risk characteristics: (1) those related to site and transport (Table 1); and (2) those related to phosphorus source and management (Table 2). The P Index results are then obtained by multiplying the sum for Table 1 by the sum for Table 2.

Table 1. Phosphorus Transport Potential Due to Site Characteristics.

Site Characteristics	Phosphorous Transport Rating					Value
Soil Erosion	No Surface Outlet 0	<5 T/A[a] 1	5-10 T/A 2	>10-15 T/A 4	>15 T/A 8	
Runoff Potential	Very Low 0	Low 1	Medium 2	High 4	Very High 8	
Leaching Potential	Very Low 0	Low 1	Medium 2	High 4	Very High 8	
Potential To Reach Water Body	Very Low 0	Low 1	Medium 2	High 4		
					Sum for Table 1: Site and Transport*	

[a] T/A = Tons per Acre per Year
* If the sum for Table 1 is 0 (Zero), then change the sum to 1 (one).

Elements of Table 1 (phosphorus transport potential due to site and transport characteristics) are as follows:

- Soil Erosion
- Runoff Potential
- Leaching Potential
- Potential to Reach Water Body

Soil Erosion

Soil erosion by water is defined as the loss of soil along the slope or unsheltered distance and is estimated from erosion prediction models. Soil erosion is not calculated for sites that have No Surface Outlet. For all other sites, soil erosion by water is predicted using the Revised Universal Soil Loss Equation (RUSLE). RUSLE is used in this index to indicate an average annual long-term movement of soil, thus potential for sediment and attached P movement toward a water body. The average annual erosion expected on fields is computed by

$$\mathbf{A = R \times K \times LS \times C \times P}$$

Where:

- **A** is the average soil loss. A is a computed value expressed in tons/acre/year.
- **R** is the rainfall factor.
- **K** is the soil erodibility factor.
- **LS** is the topographic factor.
- **C** is the cover management factor.
- **P** is the support practice factor.

Values for R, K, LS, C. and P are available for the sixty-seven counties in Florida in the UF/IFAS Nutrient Management Series, Circular 1263 and Circular 1273 through 1338 (http://edis.ifas.ufl.edu/) . A more extensive version of RUSLE methodology is in Chapter 6, Florida Agronomy Field Handbook (Florida Ecological Sciences Staff. 1999, as revised) which is available at any NRCS office. Version 2 of the Revised Universal Soil Loss Equation (RUSLE 2) estimates soil loss, sediment yield, and sediment characteristics from rill and interrill (sheet and rill) erosion caused by rainfall and its associated overland flow. RUSLE 2 uses factors that represent the effects of climatic erosivity, soil erodibility, topography, cover-management and support practices to compute erosion. Although RUSLE 2 is a second generation of RUSLE 1, it is not simply an enhancement of RUSLE 1. Instead RUSLE 2 is a new model with new features and capabilities. In calculating the erosion component of the P-Index Worksheet we have provided the user with tables from the RUSLE 1 documentation or the user may use RUSLE 2, which can be downloaded from this site:
http://fargo.nser1.purdue.edu/rusle2_dataweb/RUSLE2_Index.htm.

Runoff Potential

Usage of the following runoff potential criteria is based on a minimum of 10 observations (may be soil borings) per application area unless the number of borings identify the site as a problem area or a uniform area. At least one observation is to be made in each landform present. Examples of landforms are flats, flatwoods, depressions, terraces, rises, knolls, hills, hillsides, sideslopes, toeslopes, footslopes, etc. If there is no surface outlet for the field in consideration, the rating is Very Low (0) for Runoff Potential.

The NRCS Hydrologic Soil Groups, slope, and the presence or absence of artificial drainage are used to evaluate runoff potentials.

Runoff Potential Rating Criteria (see Table 1)

Very Low (0):

Soils in Hydrologic Soil Group A with $\geq$75% ground cover **and slopes of 8% or less.**

or:

any Hydrologic Soil Group with no surface outlet.

Low (1):

Soils in Hydrologic Soil Groups A with < 75% ground cover with surface outlet and A/D **(**with effective drainage depth of 48"**) and slopes of 8% or less** (Effective drainage is water control that is designed and maintained according to NRCS standards that will perform the desired water control.)

Medium (2):

Soils in Hydrologic Group A and A/D (with effective drainage depth of 36") **and slopes of more than 8%**.

or:

Soils in Hydrologic Groups B and B/D **(**with effective drainage depth of 36"**) and slopes of 5% or less**.

High (4):

Soils in Hydrologic Group B and B/D (with effective drainage depth of 24") **and slopes of more than 5% up to and including 8%.**

or:

Soils in Hydrologic Groups C and C/D (with effective drainage depth of 24") **and slopes of 5% or less.**

Very High (8):

Soils in Hydrologic Group B and B/D (with effective drainage depth of 36") **and slopes of more than 8%.**

or:

Soils in Hydrologic Groups C and C/D (with effective drainage depth of 24") **and slopes of more than 5%.**

or:

Soils in Hydrologic Groups D and A/D, B/D, and C/D in undrained condition.

Runoff Potentials are presented in Table 13 of the attached referenced Circulars (http://edis.ifas.ufl.edu/) based on the above criteria and the definitions of the four hydrologic soil groups below. These potentials are to be used in conjunction with the soil survey of each county. Potentials presented are interpretations, not fact. As with all interpretations, **runoff potentials shall be confirmed by on-site investigations.**

Slope and hydrologic group should be determined on-site.

- **Group A:** Soils having a high infiltration rate (low runoff potential) when thoroughly wet. These consist mainly of deep, well-drained to excessively drained sands or gravelly sands. These soils have a high rate of water transmission.
- **Group B:** Soils having a moderate infiltration rate when thoroughly wet. These consist chiefly of moderately deep or deep, moderately well-drained or well-drained soils that have moderately fine texture to moderately coarse texture. These soils have a moderate rate of water transmission.
- **Group C:** Soils having a slow infiltration rate when thoroughly wet. These consist chiefly of soils having a layer that impedes the downward movement of water or soils of moderately fine texture or fine texture. These soils have a slow rate of water transmission.
- **Group D:** Soils having a very slow infiltration rate (high runoff potential) when thoroughly wet. These consist chiefly of clays that have a high shrink/swell potential, soils that have a high water table, soils that have a claypan or clay layer at or near the surface, and soils that are shallow over nearly impervious material. These soils have a very slow rate of water transmission.

<u>Artificial Drainage</u>

The presence of artificial drainage can change the soil hydrologic group and thus lower the runoff potential of a soil. Certain wet soils have limited infiltration capacity caused by the presence of a high water table. If a soil's water table can be lowered by drainage, it is assigned a dual hydrologic soil group (A/B, A/C, A/D, B/C, B/D, or C/D). The first letter applies to the drained condition and the second to the undrained condition. Soils are assigned dual classes based upon the soil's infiltration rate and the depth of the water table. The depth to the water table can be changed through the use of drainage. Thus a B/D soil has a D hydrologic soil group in the undrained condition but may be improved to a hydrologic soil group C or group B if effectively drained. The soil could not be improved to a hydrologic group A, however, since the soils infiltration rate would still be a limiting factor regardless of the effective depth of drainage. Drained Runoff Potentials in Table 13, which are located at http://edis.ifas.ufl.edu/ have been assigned to those soils deemed drainable by NRCS. The drained runoff potentials presented are based on NRCS "Technical Release No. 55-Urban Hydrology for Small Watersheds, Amendment FL3" as follows:

Reclassification of Runoff Potential and Hydrologic Group Based on Drainage

Effective Drainage Depth [a]	Drained Runoff Potential	Drained Hydrologic Group
Less than 20 inches	Very High	D
20-36 inches	High	C
36-48 inches	Medium	B
Greater than 48 inches	Low	A

[a] The improvement of the hydrologic soil group classification is dependant upon the depth of effective drainage. Effective drainage is defined as having good surface drainage with a designed subsurface drainage system properly installed and maintained with a water removal rate of at least 0.5 inches/day. **Rarely have agricultural fields in Florida been effectively drained to a depth of more than 24 inches.**

Leaching Potential

Usage of the following leaching potential criteria is based on a minimum of 5 observations (e.g. soil borings) per 40 acres application area; more observations are required if the area is highly variable. Ground Penetrating Radar (GPR) should be used for the assessment of all karst areas. At least one observation is to be made in each landform present.

Presence or absence of a loamy/clayey layer and thicknesses of sandy layers, and presence or absence of coated sand are used to evaluate leaching potentials.

Leaching Potential Rating Criteria (see Table 1)

Very Low (0):

At least 80 percent of observations have a loamy or clayey layer at least 25 cm (10 inches) thick starting within 50 cm (20 inches). Typically, these soils are Typic Paleudults.

Low (1):

At least 80 percent of observations have a loamy or clayey layer at least 25 cm (10 inches) thick starting within 200 cm (80 inches). Typically, these soils are Arenic and Grossarenic Paleudults.

Medium (2):

At least 80 percent of observations have a loamy or clayey layer at least 25 cm (10 inches) thick starting at a depth below 200 cm (80 inches) but above seasonal high saturation **and** sand grains in the E and Bw horizons have coatings (chroma $\geq$ 3) to a depth of at least 100 cm (40 inches); or at least 80 percent of observations have no loamy or clayey layer at least 25 cm (10”) thick, but have a layer at least 200 cm (80”) thick with coated sand grains (chroma equal to or greater than 3). The entire 200 cm (80”) layer must be above seasonal high saturation.

High (4):

At least 20 percent of observations have no loamy or clayey layer,(or the loamy or clayey layer is less than 25 cm (10 inches) thick) **and** the combined thickness of layers with coated sand grains (chroma $\geq$ 3 in the E, Bw, and C horizons and any chroma in the Bh horizons) is more than 50 cm (20 inches) and less than 200 cm (80 inches).

Very High (8):

At least 20 percent of observations have no loamy or clayey layer (or the layer is less than 25 cm (10 inches) thick **and** the combined thickness of layers with coated sand grains (chroma $\geq$ 3 in the E, Bw, and C horizons and any chroma in the Bh horizons) is equal to or less than 50 cm (20 inches).

Leaching potentials are presented in Table 13 in the attached referenced Circulars based on the above criteria. Leaching potentials presented are interpretations, not fact. As with all interpretations, **leaching potentials shall be confirmed by on-site investigations.** The rating of Medium Leaching Potential may be unique to Florida. This rating is given to soils with a significant loamy/clayey layer below the normal (2m or 80 inches) soil classification depth. Use of ground penetrating radar (GPR) and/or geological investigations is needed to rate a site as having a Medium Leaching Potential **and the depth to the loamy/clayey layer must be above seasonal high saturation (water table).**

Phosphorus Runoff and Leaching Potentials Ratings for Florida Soil Survey Map Units

Runoff and leaching potentials Table 13 in the Circulars were created by comparing estimated soil properties found in the various county soil surveys with the above criteria. The runoff and leaching potentials presented are interpretations, not facts. As with all interpretations based on information in a published soil survey or other sources of estimated soil properties, **phosphorus runoff and leaching potentials shall be confirmed by on-site investigations.** However, a soil survey is an excellent place to initiate off-site investigation before making on-site determinations. For information on how to use a soil survey, see Circular 959, “Soil Ratings for Selecting Pesticides for Water Quality Goals” (Brown, et. al. 1996). However, note that phosphorus runoff and leaching potentials were derived from criteria that are different from the criteria used to derive the pesticide runoff and leaching potentials.

Potential to Reach Water Body

This parameter is used to address the potential for runoff to reach a water body. If there is no direct discharge from the edge of a field, the potential to affect a water body is considered to be "very low." If the P concentration of the runoff can be attenuated by flow through a wetland, buffer strip or overland treatment area, the potential is considered "low." If there is ditch drainage or direct discharge to a water body, the index value is increased to "medium". When there is potential for direct discharge to a lake, sinkhole, or natural stream the potential for water quality degradation by P is enhanced and the index rating is increased to "high."

Potential to Reach Water Body Rating Criteria (see Table 1)

Very Low (0):
No direct discharge from the edge of the field.

Low (1):
Discharge through wetlands, buffer area, storm water detention, or overland treatment.

Medium (2):
Ditch drainage to or direct discharge to a water body.

High (4):
Direct discharges to a lake, sinkhole, or natural stream.

Table 2. Phosphorus Loss Potential Due to Source and Management.

Phosphorus Source Management	Phosphorous Loss Rating				Value
Fertility Index Value	Soil Fertility Index X 0.025 (________ ppm P x 2 x 0.025) [a]				
P Application Source and Rate [b]	0.05 x (_____ lbs P_2O_5/acre) for fertilizer, manure, or compost 0.015 x (_____ lbs P_2O_5/acre) for biosolids 0.10 x (_____ lbs P_2O_5/acre) for waste water				
Application Method	No Surface Outlet or solids incorporated immediately or injected 0	Applies via Irrigation or solids incorporated within 1 day of application 2	Solids incorporated within 5 days of application [c] 4	Solids not incorporated within 5 days of application 6	
Waste Water Application	0.20 x _____ acre inches/acre/year				
Sum for Table 2: Phosphorus Source					

[a] From soil test (Mehlich 1) results.
[b] Initial evaluation should be N-based rates.
[c] Solids include fertilizers, composts, biosolids, and manure and other animal wastes.

Elements of Table 2 (phosphorus transport potential due to phosphorus source and management) are as follows:

- Fertility Index Value
- P Application Source and Rate
- Application Method
- Waste Water Application

Criteria

Fertility Index Value: Existing soil P levels are included in the P Index and identified as the "fertility index". The "fertility index" is defined as Mehlich-1 extractable P of a 0-15 cm (0-6 inches) depth soil sample in ppm (parts per million) multiplied by 2 to convert to pounds per acre. The 0.025 multiplication factor was selected to provide a value range similar to those used for other parameters in the P Index.

- Obtain soil samples by taking 15 to 20 small cores (for areas up to 40 acres) at random over the entire area to a depth of about 6 inches. Place the 15 to 20 plugs in a container, mix them thoroughly, and send approximately one pint of the mixed sample to the UF/IFAS Extension Soil Testing Laboratory (ESTL) or other qualified laboratory for analysis.

P Application Source and Rate: The multiplication factors for the application of P vary based on the source (fertilizer, manure, compost, biosolids, or waste water). Fertilizer, manure, and compost have the multiplier 0.05. For biosolids the multiplier is lower (0.015), because of evidence that the Fe and Al content of biosolids will decrease the P availability in biosolids-amended soils. In contrast, P in water from municipal and lagoon effluents is mostly in a soluble form and therefore the multiplier is higher (0.10).

Application Method: The application method is not a consideration for sites that have No Surface Outlet or where solids are incorporated immediately after application or injected (value 0). For all other sites, effluent applied via irrigation are typically applied frequently (weekly, bi-weekly) and in small amounts or where solids are incorporated within one day of application; therefore, the potential for P loss is low (value 2). In contrast, solids (fertilizers, compost, biosolids, manures) surface-applied and not incorporated would have a higher potential for loss, particularly through surface runoff (value 6). Incorporated solids within 5 days of application have a medium potential for loss (value 4).

Waste Water Application Volume: Excessive volumes of water may exacerbate movement of P via downward or lateral leaching, depending on the landscape. The 0.20 multiplication factor was selected to provide a value range similar to those used for other parameters in the P Index.

<u>Resulting P Index</u>

The P Index is obtained by multiplying the site and transport characteristics sum (Table 1) by the phosphorus source sum (Table 2). The result is interpreted according to guidelines in Table 3 (below).

On sites with a LOW or MEDIUM vulnerability rating, it is possible to use a nitrogen-based budget to determine application rates. On sites with a HIGH or VERY HIGH vulnerability rating, it is necessary to use a phosphorus-based budget to determine application rates.

Table 3. Assessing the P Index Results

P Index for Site	Generalized Interpretation of P Index for Site
<75	**LOW** potential for P movement from the site. If current practices are maintained there is a low probability of an adverse impact to surface waters from P losses at this site. N-based nutrient management planning is satisfactory for this site. Soil P levels and P loss potential may increase in the future due to N-based nutrient management.
75-150	**MEDIUM** potential for P movement from this site. The chance for an adverse impact to surface waters exists. *Nitrogen-based nutrient management planning is satisfactory for this site when conservation measures are taken to lessen the probability of P loss*. Soil P levels and P loss potential may increase in the future due to N-based nutrient management.
151-225	**HIGH** potential for P movement from the site and for an adverse impact on surface waters to occur unless remedial action is taken. Soil and water conservation and P management practices are necessary (if practical) to reduce the risk of P movement and water quality degradation. If risk cannot be reduced then a P-based management budget based on soil test crop P requirements will be utilized.
> 225	**VERY HIGH** potential for P movement from the site and for an adverse impact on surface waters. Remedial action is required to reduce the risk of P movement. All necessary soil and water conservation practices, plus a P- based management plan must be put in place to avoid the potential for water quality degradation. The P-based management plan will be based on less than soil test crop P requirement to reduce P over a defined period (not to exceed 20 years).

Assessing the P Index Results

The numerical result of the P Index has no absolute value, but is immediately translated into a qualitative rating (LOW, MEDIUM, HIGH, or VERY HIGH). For each qualitative rating a description is given for the level of concern that each specifically assessed field has for P loss potential (Table 3). Some general guidance is given for each qualitative level as to the intensity and type of remedial action or mitigation that would be necessary to reduce P loss risk.

Conservation Planning Notes

Since output from the P Index includes information that is specific to each of the site and transport characteristics (Table 1) and phosphorus source and management (Table 2), the conservation planner can identify which characteristics/management that have the greatest influence in determining the final vulnerability rating and may be targeted for remedial action. Table 4 (below) may be used to record notes to explain, clarify, and/or define site characteristics and source and management used to evaluate a site. Each factor can be revisited and planning changes made, thereby changing the resulting P Index. For example, terraces can be installed, thereby lowering soil erosion and the final P Index. Similarly, the P Index can be lowered by reducing the planned P application rate.

Table 4. Conservation Planning Notes

Client Name:	County:	Date:
Planner:	Fields:	Crop:
Site and Transport Characteristics	**Remarks**	
Soil Erosion		
Runoff Potential		
Leaching Potential		
Potential to Reach Water Body		
Phosphorus Source Management	**Remarks**	
Fertility Index Value		
P Application Source and Rate		
Application Method		
Waste Water Application		

CONSIDERATIONS FOR REDUCING VULNERABILITY

After assessing the P index results on present conditions, the planner should determine what factors are creating the highest levels of concern and evaluate the feasibility of making changes to reduce the vulnerability rating to an acceptable level. This may require several trials and combinations of various possible decisions to achieve the desired reduction of Phosphorus leaving the site. There may be sites or portions of the site that the vulnerability cannot be reduced enough to apply animal by-products. In this case alternate sites would need to be considered.

Portions of a site, when large enough, that has significant characteristics should be considered as separate sites to determine if animal by-products may be applied to that portion within the rating criteria.

The following is a list of NRCS conservation practice standards, located in the Field Office Technical Guide Section IV, and possible effects related to the transport potential and management practice factors of the P index. Implementation of one or more practices may have positive effects on some factors while causing negative effects on other factors. For example, Terraces (600) can be installed, thereby lowering soil erosion and the final P Index. Similarly, Use Exclusion (472) can exclude an area with a significantly higher P Index than the surrounding area thereby, lowering the P Index for the entire area of concern.

Only those conservation practices listed at http://www.fl.nrcs.usda.gov/technical/conservation.html are considered capable of reducing the P Index. Specifically, soil amendments do not reduce the P Index.

NRCS Conservation Practice Standard Name and Code Number	Part A - Transport				Part B - Management Practices			
	Soil Erosion	Runoff	Leaching	Water body	Fertility Index	P App. Rate	Applica -tion Method	Waste Water Volume
Residue management (329A, 329B, 329C, 344)	Decrease	Decrease	Increase	Increase/ decrease	Increase/ decrease	LC [a]	LC	LC
Constructed Wetlands (656)	Decrease	Decrease	LC	Decrease	LC	LC	LC	LC
Conservation Crop Rotation (328)	Decrease /increase	Decrease /increase	Decrease /increase	Decrease/ increase	Decrease	Increase	LC	Increase
Contour Buffer Strips (332)	Decrease	Decrease	Increase/ decrease	Decrease	Decrease	LC	LC	LC
Stripcropping (585)	Decrease	Decrease	Increase/ decrease	Decrease	Decrease	Increase	Increase	LC
Diversion (362)	Decrease	Decrease	Increase/ decrease	Decrease	LC	LC	LC	LC
Field Border (386)	Decrease	Decrease	LC	Decrease	LC	LC	LC	LC
Filter Strip (393)	Decrease	Decrease	Increase	Decrease	LC	LC	LC	LC
Forage Harvest Management (511)	LC	LC	LC	LC	Decrease	Increase	LC	Increase
Irrigation Water Management (449)	Decrease	Decrease	Decrease	LC	Decrease	Decrease /increase	Decrease	Decrease
Nutrient Management (590)	Decrease	Decrease	Decrease	Decrease/ increase	Decrease/ increase	Decrease /increase	Decrease	LC
Prescribed Grazing (528A)	Decrease	Decrease	LC	Decrease	Decrease	LC	LC	LC
Terrace (600)	Decrease	Decrease	Increase	Decrease	LC	LC	LC	LC
Runoff Management System:(includes several engineering practices [b]	Decrease /increase	Decrease	Increase	Decrease/ increase	LC	LC	LC	LC
Use Exclusion (472)	Decrease	Decrease	Decrease	Decrease	Decrease	Decrease	LC	LC
Waste Utilization (633)	LC	LC	Decrease	LC	decrease	decrease	Decrease	Decrease
Mulching (484)	Decrease	Decrease /increase	Decrease /increase	Decrease/ increase	Decrease/ increase	LC	LC	LC

[a] LC is used to designate little or no change or effect on the factor.
[b] See http://www.fl.nrcs.usda.gov/technical/conservation.html for complete list

Glossary (as used in the P Index the following definitions apply)

No Surface Outlet – The combination of slope and permeability of the application site that will not discharge surface flow from that site in a 2 year – 24 hour rainfall event.

(This level of evaluating runoff is not intended to require calculation for the rainfall events but is intended to evaluate those sites that do not have external surface flows during most years. Where these sites occur, additional comments may need to be recorded on the back of form FL-CPA-41)

Compost – animal wastes and plant debris that has gone through the composting process.

Biosolids – Residuals, domestic wastewater residuals and/or septage as defined in Chapter 62-640 Florida Administrative Code. Biosolids include co-compost with a minimum of 50% biosolids.

Landform - Any physical, recognizable form or feature of the earth's surface, having a characteristic shape and produced by natural causes.

Examples of individual landforms and their definitions are:

Karst - Topography with sinkholes, caves, and underground drainage that is formed in limestone, gypsum, or other rocks by dissolution, and that is characterized by sinkholes, caves, and underground drainage.
Knoll - A small, low, rounded hill rising above adjacent landforms.

Subsurface Drainage – Lowering of the water table in order to improve vegetative growth, remove surface runoff from wet areas, or relieve artesian pressure. Subsurface drainage can be achieved by either using drainage tile or drainage ditches, typically spaced at regular intervals.

References

Brown, R.B., A.G. Hornsby, and G.W. Hurt. 1996. Soil Ratings for Selecting Pesticides for Water Quality Goals. Circular 959. Florida Cooperative Extension Service, University of Florida, Gainesville, FL. http://edis.ifas.ufl.edu/ss056

Florida Ecological Sciences Staff. 1999. Florida Agronomy Field Handbook, chapter 6. USDA, NRCS, Gainesville, FL.

Hurt, G.W., R.S. Mylavarapu and W.D. Tooke. 2001-2002. Computational tools for field implementation of the Florida phosphorous index, sixty seven counties of Florida, UF/IFAS Nutrient Management Series, Circular 1263 and Circular 1273 through Circular 1338. Florida Cooperative Extension Service, Institute of Food and Agricultural Sciences, University of Florida, Gainesville, FL.

*County	Publication Number
Alachua County (2004)	Circular-1263 http://edis.ifas.ufl.edu/SS319
Highlands County (2004)	Circular-1273 http://edis.ifas.ufl.edu/SS333
Lafayette County (2004)	Circular-1275 http://edis.ifas.ufl.edu/SS335
Glades County (2004)	Circular-1274 http://edis.ifas.ufl.edu/SS334
Escambia County (2004)	Circular-1280 http://edis.ifas.ufl.edu/SS340

Jackson County (2004)	Circular-1281 http://edis.ifas.ufl.edu/SS341
Santa Rosa County (2004)	Circular-1283 http://edis.ifas.ufl.edu/SS343
Okaloosa County (2004)	Circular-1284 http://edis.ifas.ufl.edu/SS344
Walton County (2004)	Circular-1285 http://edis.ifas.ufl.edu/SS345
Holmes County (2004)	Circular-1286 http://edis.ifas.ufl.edu/SS346
Washington County (2004)	Circular-1287 http://edis.ifas.ufl.edu/SS347
Gadsden County (2004)	Circular-1288 http://edis.ifas.ufl.edu/SS348
Leon County (2004)	Circular-1289 http://edis.ifas.ufl.edu/SS349
Jefferson County (2004)	Circular-1290 http://edis.ifas.ufl.edu/SS350
Madison County (2004)	Circular-1291 http://edis.ifas.ufl.edu/SS351
Hamilton County (2004)	Circular-1292 http://edis.ifas.ufl.edu/SS352
Gilchrist County (2004)	Circular-1278 http://edis.ifas.ufl.edu/SS338
Suwannee County (2004)	Circular-1279 http://edis.ifas.ufl.edu/SS339
Levy County (2004)	Circular-1282 http://edis.ifas.ufl.edu/SS342
Baker County (2004)	Circular-1293 http://edis.ifas.ufl.edu/SS353
Bradford County (2004)	Circular-1294 http://edis.ifas.ufl.edu/SS354
Columbia County (2004)	Circular-1295 http://edis.ifas.ufl.edu/SS355
Duval County (2004)	Circular-1296 http://edis.ifas.ufl.edu/SS356
Nassau County (2004)	Circular-1297 http://edis.ifas.ufl.edu/SS357
Union County (2004)	Circular-1298 http://edis.ifas.ufl.edu/SS358
Marion County (2004)	Circular-1299 http://edis.ifas.ufl.edu/SS359
Okeechobee County (2004)	Circular-1276 http://edis.ifas.ufl.edu/SS336
Orange County (2004)	Circular-1300 http://edis.ifas.ufl.edu/SS360
Lake County (2004)	Circular-1301 http://edis.ifas.ufl.edu/SS361
Sumter County (2004)	Circular-1302 http://edis.ifas.ufl.edu/SS362
Pasco County (2004)	Circular-1303 http://edis.ifas.ufl.edu/SS363
Polk County (2004)	Circular-1304 http://edis.ifas.ufl.edu/SS364
Osceola County (2004)	Circular-1305 http://edis.ifas.ufl.edu/SS365
St. Lucie County (2004)	Circular-1306 http://edis.ifas.ufl.edu/SS366
Martin County (2004)	Circular-1307 http://edis.ifas.ufl.edu/SS367
Palm Beach County (2004)	Circular-1308 http://edis.ifas.ufl.edu/SS368
Hendry County (2004)	Circular-1309 http://edis.ifas.ufl.edu/SS369
Broward County (2004)	Circular-1310 http://edis.ifas.ufl.edu/SS370
Dade County (2004)	Circular-1311 http://edis.ifas.ufl.edu/SS371
Monroe County (2004)	Circular-1312 http://edis.ifas.ufl.edu/SS372
Collier County (2004)	Circular-1313 http://edis.ifas.ufl.edu/SS373
Dixie County (2004)	Circular-1277 http://edis.ifas.ufl.edu/SS337
Hernando County (2004)	Circular-1314 http://edis.ifas.ufl.edu/SS374
Pinellas County (2004)	Circular-1315 http://edis.ifas.ufl.edu/SS375
Hillsborough County (2004)	Circular-1316 http://edis.ifas.ufl.edu/SS376
Citrus County (2004)	Circular-1317 http://edis.ifas.ufl.edu/SS377
Wakulla County (2004)	Circular-1318 http://edis.ifas.ufl.edu/SS378
Taylor County (2004)	Circular-1319 http://edis.ifas.ufl.edu/SS379
Manatee County (2004)	Circular-1320 http://edis.ifas.ufl.edu/SS380
Sarasota County (2004)	Circular-1321 http://edis.ifas.ufl.edu/SS381
Charlotte County (2004)	Circular-1322 http://edis.ifas.ufl.edu/SS382

Lee County (2004)	Circular-1323 http://edis.ifas.ufl.edu/SS383
Hardee County (2004)	Circular-1324 http://edis.ifas.ufl.edu/SS384
DeSoto County (2004)	Circular-1325 http://edis.ifas.ufl.edu/SS385
Indian River County (2004)	Circular-1326 http://edis.ifas.ufl.edu/SS386
Brevard County (2004)	Circular-1327 http://edis.ifas.ufl.edu/SS387
Seminole County (2004)	Circular-1328 http://edis.ifas.ufl.edu/SS388
Volusia County (2004)	Circular-1329 http://edis.ifas.ufl.edu/SS389
St. Johns County (2004)	Circular-1330 http://edis.ifas.ufl.edu/SS390
Putnam County (2004)	Circular-1331 http://edis.ifas.ufl.edu/SS391
Flagler County (2004)	Circular-1332 http://edis.ifas.ufl.edu/SS392
Clay County (2004)	Circular-1333 http://edis.ifas.ufl.edu/SS393
Bay County (2004)	Circular-1334 http://edis.ifas.ufl.edu/SS394
Calhoun County (2004)	Circular-1335 http://edis.ifas.ufl.edu/SS395
Franklin County (2004)	Circular-1336 http://edis.ifas.ufl.edu/SS396
Gulf County (2004)	Circular-1337 http://edis.ifas.ufl.edu/SS397
Liberty County (2004)	Circular-1338 http://edis.ifas.ufl.edu/SS398